Emergency procedures on the descending thoracic aorta in the endovascular era

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Background: **Thoracic endovascular aortic repair (TEVAR), initially developed for the treatment of degenerative aneurysms of the descending thoracic aorta, has been applied to the entire spectrum of descending thoracic aortic pathology in both the elective and emergent settings. This single center study evaluates the effectiveness of TEVAR for the treatment of acute surgical emergencies involving the descending thoracic aorta, including traumatic aortic disruption (TAD), ruptured descending thoracic aneurysm (RDTA), and acute complicated Type B dissection (cTBD).**

Methods: **A retrospective review of the medical records of all patients undergoing emergent TEVAR at the University of Mississippi Medical Center between August 2007 and November 2010 was undertaken. Patients were studied for 30-day survival, complications, type of device used for the repair, and technical aspects of the procedure.**

Results: **A total of 44 patients (59% male) with an average age of 49 years (range, 16-87 years) underwent emergent TEVAR during the study period. The technical success rate was 100%, with no patient requiring emergent open surgery for conditions involving the descending thoracic aorta at our institution during the study period. The majority (73%) of the repairs were accomplished using commercially available thoracic stent grafts. Abdominal endograft proximal extension cuffs were used in 12 (38%) of the 32 patients undergoing repair of TAD. Twenty-one patients (48%) required coverage of the left subclavian artery, two (10%) of whom subsequently required subclavian artery revascularization. Procedure-related complications included two strokes, one spinal cord ischemia, one unintentional coverage of the left carotid artery, one episode of acute renal failure, and three access site injuries. One patient undergoing repair of TAD had collapse of the stent graft in the early postoperative period. He was successfully treated by placement of an additional stent graft. Seven patients (16%) died within 30 days of surgery. Three of the deaths occurred in patients who had successfully undergone repair of a TAD and died of associated injuries.**

Conclusions: **Emergent TEVAR has become the treatment of choice for acute surgical emergencies involving the descending thoracic aorta. Short-term morbidity and mortality compare favorably with historic results for emergent open surgical procedures on the descending thoracic aorta. Survival is highest in patients undergoing repair of TAD. Using current endograft technology, nearly all emergent conditions of the descending thoracic aorta can be successfully treated with TEVAR. (J Vasc Surg 2011;54:1298-302.)**

Catastrophes involving the descending thoracic aorta have long been particularly challenging for surgeons. Many patients do not survive the initial event and never undergo an attempt at repair. Emergent open operative repair of the descending thoracic aorta, the traditional gold standard, is associated with significant operative mortality and morbidity, making these procedures some of the riskiest and most difficult undertaken by vascular surgeons.[1,2]

Initially developed for the elective repair of degenerative aneurysms, thoracic endovascular aortic repair (TEVAR) has quickly become the treatment of choice for all conditions, both elective and emergent, involving the descending thoracic aorta.[1,3-6] The result has been a decrease in both operative mortality and morbidity for patients with these conditions. The current study looks at the experience of a single center with emergent endovascular repair of descending thoracic aortic catastrophes.

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Competition of interest: none.

Presented at the Thirty-fifth Annual Meeting of the Southern Association for Vascular Surgery, Naples, Fla, Jan 19-22, 2011.

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The editors and reviewers of this article have no relevant financial relationships to disclose per the JVS policy that requires reviewers to decline review of any manuscript for which they may have a competition of interest.

0741-5214/$36.00

doi:10.1016/j.jvs.2011.05.010

METHODS

A retrospective review of all patients undergoing emergent procedures on the descending thoracic aorta at the University of Mississippi Medical Center between August 2007 and November 2010 was performed. All patients with acute surgical emergencies involving the descending thoracic aorta, including traumatic aortic disruption (TAD), ruptured descending thoracic aneurysm (RDTA), and acute complicated Type B dissection (cTBD) were included in the study. Acute cTBD was defined as visceral or lower extremity malperfusion syndrome or aortic rupture in the setting of an acute Type B aortic dissection unresponsive to medical therapy.

Patients with complications related to Type A aortic dissections or chronic Type B aortic dissections were excluded. Patients with symptomatic or rapidly expanding, but not ruptured, descending thoracic aneurysms were excluded. Patients with minimal TAD not requiring repair, as defined by the Society for Vascular Surgery clinical practice guidelines were excluded.[1]

Table I. Distribution of aortic pathology, age, gender, subclavian artery coverage, type and number of devices used, and mortality

Type of aortic pathology (N)	*Mean age (range)*	*Male*	*Subclavian artery coverage*	*Type of device used (N)*	*Mean number of devices used (range)*	*30-day survival*
TAD (n = 32)	43 (16-77)	21 (70%)	16 of 32 (50%)	Thoracic (n = 20) Abdominal cuff (n = 12)	Thoracic −1.4 (1-3) Abdominal cuff −3.8 (2-6)	29 of 32 (91%)
RDTA (n = 7)	68 (54-87)	2 (29%)	3 of 7 (43%)	Thoracic (n = 7)	Thoracic −1.7 (1-2)	4 of 7 (57%)
cTBD (n = 4)	67 (50-77)	3 (75%)	2 of 4 (50%)	Thoracic (n = 4)	Thoracic −1.8 (1-3)	3 of 4 (75%)
Spontaneous distal aortic tear (n = 1)	42	0 (0%)	0 of 1 (0%)	Thoracic (n = 1)	Thoracic −1	1/1 (100%)
Total (n = 44)	49 (16-87)	26 (59%)	21 of 44 (48%)	Thoracic (n = 32) Abdominal cuff (n = 12)	Thoracic −1.5 (1-3) Abdominal cuff −3.8 (2-6)	37 of 44 (84%)

cTBD, Complicated type B dissection; *RDTA,* ruptured descending thoracic aneurysm; *TAD,* traumatic aortic disruption.

Medical records, preoperative computed tomography (CT) scans, and intraoperative imaging studies were reviewed for all patients. Data collected included demographic information, patient comorbid conditions, details of the procedure, and the patient's hospital course. The primary outcome measures were technical success, procedure-related mortality, and morbidity. The decision regarding the type of device used, whether or not to give heparin, or to employ spinal drainage was left to the discretion of the operating surgeon.

In all cases, the exact nature of the aortic catastrophe was diagnosed by CT scan prior to TEVAR. Patients presenting in extremis and deemed not to be surgical candidates, and those declining treatment were excluded from the study. Endovascular technical success was defined as successful treatment of the underlying aortic pathology with TEVAR. Patients were informed that the use of endografts for the treatment of these conditions represents an "off label" use of the device. The Institutional Review Board of the University of Mississippi Medical Center approved the retrospective review.

RESULTS

During the study period, all patients with catastrophes of the descending thoracic aorta requiring emergent surgical intervention were treated by vascular surgeons using commercially available thoracic endografts or abdominal endograft proximal extension cuffs that are stocked in our operating room. All patients except one were treated with Excluder or TAG (W. L. Gore, Flagstaff, Ariz) endografts. The study group comprised 44 patients. Patient age, gender, and the distribution of aortic pathology are detailed in Table I. Patients with TAD were younger than those with RDTA and cTBD.

No patients underwent open repair during the study period, and technical success was achieved in all 44 patients undergoing endovascular repair. In eight patients (18%), percutaneous femoral artery access was used. Preoperative spinal drainage was not used in any patient. Heparin administration was inconsistent.

Seven patients in the study group died, resulting in an overall 30-day survival of 84%, ranging from 57% in patients with RDTA to 91% in patients with TAD (Table I). The deaths are detailed in Table II. The three deaths in the TAD group were the result of associated injuries, not the aortic transaction.

Two patients in the RDTA group had aortoesophageal fistulae. One was related to an esophageal perforation secondary to dilatation of the esophagus, with subsequent pseudoaneurysm formation and rupture. The ruptured pseudoaneurysm was successfully treated, but the patient was subsequently discovered to have cancer, and care was withdrawn. The other resulted from the spontaneous rupture of a mycotic aortic pseudoaneurysm into the esophagus. This patient was successfully treated with TEVAR. The esophagus was debrided, closed, and a muscle flap interposed between the esophagus and aorta. He is alive and well 2 years later.

The other two deaths in the RDTA group were in patients with significant cardiac disease. One presented in shock, was resuscitated, had successful endovascular exclusion of the RDTA, but suffered an acute myocardial infarction and died of cardiac failure in the operating room. The other died of a myocardial infarction in the early postoperative period after successful TEVAR. The death in the cTBD group was the result of postoperative pneumonia and respiratory failure after successful TEVAR.

All patients with RDTA and cTBD were treated using commercially available thoracic endografts, while 38% of patients with TAD were treated with abdominal endograft proximal extension cuffs (Table I). When abdominal endograft proximal extension cuffs were used, a mean of 3.8 devices were required, compared with only 1.5 devices when thoracic endografts were used. The decision regarding the type of device to use was left to the discretion of the operating surgeon, and was based on the patient's anatomy. Abdominal endograft proximal extension cuffs were used primarily in cases of small diameter descending thoracic aortas.

Two patients in the TAD group required construction of an iliac conduit for endograft delivery. One patient had an iliac system that was too small to accommodate the delivery device. The other had a small thoracic aorta that was treated with abdominal endograft proximal extension

Table II. Details of mortality and complications

Patient	*Type of aortic pathology*	*Death or complication*
25-year-old male	TAD and closed head injury	Death from associated injuries
60-year-old male	TAD with closed head injury and pulmonary contusion	Death from associated injuries
39-year-old male	TAD with multiple intra-abdominal injuries	Death from associated injuries
34-year-old male	TAD	Endograft collapse
19-year-old male	TAD	Unintentional coverage of left common carotid artery
44-year-old male	TAD	Left upper extremity ischemia after coverage of left subclavian artery
44-year-old female	TAD	Left upper extremity ischemia after coverage of left subclavian artery
24-year-old male	TAD	Femoral artery thrombosis
77-year-old female	cTBD with visceral malperfusion	Death from pneumonia and respiratory failure
50-year-old male	cTBD with visceral malperfusion	Stroke and spinal ischemia
77-year-old male	cTBD with visceral malperfusion	Renal failure
87-year-old female	RDTA	Death from myocardial infarction and intraoperative cardiac failure
84-year-old female	RDTA	Torn external iliac artery Death from myocardial infarction on postoperative day five
70-year-old male	RDTA (pseudoaneurysm secondary to esophageal cancer)	Death from esophageal cancer
54-year-old female	RDTA	Femoral artery thrombosis, superficial wound infection and stroke

cTBD, Complicated type B dissection; *RDTA,* ruptured descending thoracic aneurysm; *TAD,* traumatic aortic disruption.

cuffs. A conduit was used to access the common iliac artery so the short delivery system of the abdominal endograft proximal extension cuff would reach the proximal descending thoracic aorta. Three patients required iliac angioplasty and stenting in order to accommodate the device delivery system.

The left subclavian artery was covered in 48% of the cases (Table I). The frequency of subclavian artery coverage was similar regardless of the type of aortic pathology being treated. Two (10%) of the 21 patients in whom the subclavian artery was covered required revascularization. One was performed acutely at the time of repair of the TAD because of poor collateral flow to the left arm. The other patient had persistent ischemic hand pain. Carotid to subclavian bypass was performed 5 weeks after TEVAR with complete resolution of symptoms.

Nine patients (20%) had procedure-related complications (Table II). There were three access site complications. One patient suffered a tear of the external iliac artery, which was reconstructed with a graft. Two others had early postoperative thrombosis of the common femoral artery requiring thrombectomy. One of these patients developed a superficial wound infection.

Two patients in the TAD group had device-related complications. One had a small aorta that was repaired with an oversized thoracic endograft. The graft collapsed in the early postoperative period. An additional endograft was placed, with full expansion. In one patient, the left common carotid artery was nearly completely covered by the endograft, and flow significantly diminished. Open exposure of the common carotid artery was performed for retrograde delivery of a balloon expandable bare metal stent, which successfully restored flow. The patient did well and has had no neurologic symptoms or evidence of carotid stenosis 1 year after treatment.

Two patients suffered neurologic complications. One patient with an RDTA had a stroke 4 days postoperatively. She was discovered to have a high grade internal carotid artery stenosis, underwent carotid endarterectomy, and subsequently had full neurologic recovery. The other developed spinal ischemia and lower extremity weakness after treatment of a cTBD with visceral malperfusion syndrome. A lumbar drain was placed, and the lower extremity weakness recovered fully. The same patient subsequently had a stroke manifest by upper extremity weakness which eventually improved. One patient with a cTBD and visceral malperfusion had progression of renal failure despite successful intervention, and ultimately became dialysis-dependent.

DISCUSSION

The widespread application of TEVAR to the treatment of acute surgical emergencies involving the descending thoracic aorta has resulted in a dramatic decrease in both operative mortality and morbidity for these conditions.[2] The results of the current study compare favorably with other published reports detailing the use of TEVAR in these conditions, and compare favorably with historical data for open surgical repair.

Over the last several years, there has been a rapid shift to TEVAR for the treatment of TAD. Open repair of TAD is associated with an operative mortality of up to 28% and paraplegia rate of 16%.[6-9] Our mortality of 9% with no

incidence of paraplegia in patients with TAD treated by TEVAR is similar to the results of a systematic review of the literature, demonstrating an overall mortality rate of 9% and paraplegia rate of 3% in 7768 patients undergoing TEVAR for TAD.[10] Recently published Society for Vascular Surgery practice guidelines suggest that TEVAR should be the standard therapy for the treatment of TAD.[1]

Contemporary series have demonstrated mortality rates of up to 30% for open repair of RDTA.[11-13] Our series had a slightly higher mortality rate of 43%, but the number of patients with RDTA was small. Two of the deaths were expected; one in a patient who presented in shock and the other in a patient with terminal esophageal cancer.

Medical therapy has long been the standard for uncomplicated type B aortic dissection,[14] with surgery reserved for patients who fail medical therapy. Open surgery in the setting of cTBD has a reported mortality upwards of 30%.[15,16] Although only four patients in our series had cTBD, our results are favorable compared with open repair.

No patient suffered permanent paraplegia in our series, which is similar to the reported incidence in other series of patients undergoing emergency TEVAR.[2,17] Preprocedure spinal drainage was not used in this series. Because of the low incidence of spinal ischemia in TEVAR for TAD, we do not believe it is indicated in these patients. Patients with RDTA are typically unstable, and usually there is not time for spinal drain placement. In the cases of cTBD, preprocedure spinal drain placement may be advantageous. Indeed, the single case of spinal ischemia in this series was in a patient with cTBD. Fortunately, he recovered completely after postoperative drain placement, as has been reported previously.[18]

The appropriate use of heparin in these conditions has not yet been determined.[1] Heparin use varied significantly in our series. Heparin was avoided in patients with head injuries and significant bleeding. Many patients received "low dose" heparin during the procedure. The experience and judgment of the operating surgeon is paramount in determining the appropriate use of heparin in these patients.

One can argue that the benefits of TEVAR in an emergency setting are even greater than those seen with elective procedures. The overall 30-day mortality of 16% in this cohort of patients undergoing emergent repair, including no cases of permanent paraplegia, represents significant improvement compared with historical results of open surgical repair for these conditions. The results approach the 10% operative mortality seen with elective open surgery on the descending thoracic aorta.[19,20] While elective TEVAR offers a significant reduction in mortality and morbidity compared with elective repair of thoracic aneurysm, the reduction in mortality and morbidity seen with emergency TEVAR is even greater.

The most striking aspect of the current study is the fact that all emergent operations performed upon the descending thoracic aorta were done using TEVAR. There were no open repairs of TAD, RDTA, or cTBD during the study time frame. All attempts at TEVAR were successful. While it is obvious that not all patients are candidates for TEVAR and that not all attempts at TEVAR will be successful, this study demonstrates that the vast majority of patients with acute surgical emergencies of the descending thoracic aorta can be successfully treated using TEVAR. As newer devices are developed designed specifically for TAD and cTBD, the results will only continue to improve.

CONCLUSION

Using currently available commercial thoracic endografts or abdominal endograft proximal extension cuffs that are designed for elective repair of degenerative aneurysms, emergent TEVAR can be performed in most patients with catastrophes of the descending thoracic aorta. Short-term results compare favorably with historic results for emergent open surgical procedures on the descending thoracic aorta. Emergent TEVAR has become the treatment of choice for acute surgical emergencies involving the descending thoracic aorta, and should be considered the first line of therapy for all emergent conditions involving the descending thoracic aorta.

AUTHOR CONTRIBUTIONS

Conception and design: MM, FR, AB, ZB
Analysis and interpretation: MM, ZB
Data collection: MM, TB, ZB
Writing the article: MM
Critical revision of the article: MM, FR, AB, TB, ZB
Final approval of the article: MM
Statistical analysis: Not applicable
Obtained funding: Not applicable
Overall responsibility: MM

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Submitted Feb 21, 2011; accepted May 2, 2011.

DISCUSSION

Dr Jeff B. Dattilo (*Nashville, Tenn*). I'd like to thank the Society for the privilege of discussing this well written paper. I appreciate the timeliness with which the authors offered the paper to me for review. Dr Mitchell and his esteemed colleagues from the University of Mississippi have concisely reported their single institution retrospective data concerning use of TEVAR in the treatment of descending thoracic emergencies. Their data involve three unique patient populations with three distinct surgical and medical pathophysiologies: traumatic aortic disruption, rupture of descending thoracic aortic aneurysms, and complicated type B dissection. Their results demonstrate improved outcomes with regard to major morbidity and mortality with use of currently available commercial aortic devices as compared to historic open controls. They suggest that this technology can be safely used in all of these emergent clinical scenarios. Use of this technology required coverage of the subclavian artery in half of the patients with a resultant paucity of post intervention subclavian artery revascularization, which is not necessarily dissimilar to many published reports.

I have three questions: With the nearly infectious use of endoluminal therapy for treating traumatic aortic disruptions, what are the author's thoughts on conservative, nonoperative management of these injuries? Do you use a scoring system of the intimal or aortic disruption with protocols to determine which patients to intervene upon acutely?

Second, I noticed in your ruptured descending thoracic aortic group, you had two individuals well into there 80s die subsequent to graft placement. You had seven patients in that group. Is your vascular unit evaluating the advanced-aged patient and there preoperative risk to determine if endovascular therapy should be offered at all in these patients?

Last, I'd like your thoughts on the development of second and third generation aortic stent grafts particularly designed for the acutely angled aortic arch, meaning the typical, young patients most often seen with acute traumatic arch injury. Are we obligated as a subspecialty to better understand the long-term ramifications of having these stents in this exceptionally dynamic position for what could be several decades in these young patients?

Dr Mitchell, it was a pleasure to have the opportunity to review and discuss this paper. I wish you good fortune during the publication process and look forward to your answers.

Dr Marc E. Mitchell. Thank you, Dr Dattilo. We are seeing more and more traumatic aortic disruptions, and I believe there are two reasons. Most patients with any significant degree of trauma have a CT scan of the chest and CT scan technology has improved to the point where we are identifying many minor aortic injuries now which we never would have picked up in the past. In our practice, we probably watch or treat conservatively more aortic injuries than we operate on. In preparing this manuscript, we reviewed the CT scans of all the patients we treated and in retrospect, there was only one patient who probably could have been treated nonoperatively. The SVS recently published guidelines for the treatment of traumatic aortic injuries. They are somewhat subjective, but we tend to follow those guidelines and do not operate on patients with minor intimal injuries.

The second question is about elderly patients with ruptured aneurysms. We did not specifically look at patients with reputed aneurysms who we not operated on, but during the study period, they were probably as many if not more patients who were treated expectantly than were offered surgery. We don't have a protocol, but we look at each patient individually. There are patients with little chance of surviving an operation, but the family still insists on surgery. Conversely, there are patients in whom we recommend surgery, but they refuse.

The third question is about new devices. As was made obvious from the complication of a graft collapse in a young trauma patient, there are certainly limitations to the current devices. I have no doubt that the newer generation of devices will make those complications less common and will improve our ability to treat these patients.

The question about leaving a stent in a young patient's aorta for decades is very interesting. I'm not sure if we will be operating on these patients in several years and replacing their aortas with grafts. Even if that is the case, I believe TEVAR in the acute setting is a better option than doing an open repair in a critically ill patient with multisystem trauma. It may turn out that the endovascular repair is a type of bridge therapy in some patients. The benefits of TEVAR in the face of multisystem trauma make it superior to open repair and I believe it's the right thing to do.